LEVEL II

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7WW/TN-80/002

SEVENTH WEATHER WING

SATELLITE DERIVED WINDS

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7TH WEATHER WING (MAC)

SCOTT AFB, ILLINOIS 62225

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This REPORT Explains how satellite derived winds are produced, discusses reliability and accuracy of satellite winds, possible uses, and provides instructions for decoding TWXX-series bulletins. It Identifies differences in decoding procedures for U.S., Japanese, and European GOES wind bulletins. And it also Provides example of bulletin and how data may be plotted.

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PREFACE

Captain Heckman is a reserve officer assigned to 7WW/DON. He is a full-time meteorologist for the National Environmental Satellite Service (NESS) in Kansas City. The following was written and compiled by Capt Heckman during inactive duty training.

This Tech Note is the only known publication which identifies, all available satellite derived wind bulletins and provides complete and comprehensive decoding instructions for U.S., European, and Japanese data.

SATELLITE DERIVED WINDS

1. INTRODUCTION. Forecasting winds over data-sparse areas of the globe is at best an inexact procedure. The best guidance available to most forecasters are numerical weather prediction (NWP) products. However, forecasters need to constantly check the accurancy of the forecast products. The accuracy of the forecast product is only as good as the quality of the observation data used to generate the forecast. If the input to the numerical model is poor quality data, subsequent forecast products will likewise be poor.

For many years the best data source available to check the accuracy of NWP products were AIREPs of upper level winds. These reports allowed forecasters to evaluate the quality of NWP products over well-traveled routes, but did little to aid the military forecaster briefing aircrews flying other than standard routes and altitudes. Now data are available to help alleviate this problem.

These new data are wind vectors developed from geostationary earth orbiting satellite (GOES) imagery. Several countries currently operate GOES systems, making possible many additional observations. This Tech Note is designed to introduce AWS forecasters to these data, give a brief description of the process used to derive these data, discuss their accuracy, give detailed instructions how to decode the satellite observation (SATOB) report, and suggest possible uses for the data.

2. GENERATION OF SATELLITE WIND VECTORS. Satellite wind vectors are made available by National Environmental Satellite Service (NESS) through the Satellite Wind Section (SWS) for low, middle, and high levels. The primary mission of SWS is twofold:

- Generate and quality control middle and high level wind vectors.

- Generate and quality control low level wind vectors and quality control NWP-generated low level vectors.

For further information see Green, et al. (1975) and Young (1975).

A completely objective computer algorithm has been designed for the generation of low level wind vectors. The process involves ingesting consecutive GOES images (a picture pair) into the computer, accurately defining the position of the two images relative to a surface feature, and then conducting several statistical tests. These tests measure numerous lag correlations between picture pairs, such as cloud displacement between two 30-minute interval images. After these complex processes are completed, the vectors are edited by SWS through a comparison with latest 850mb and surface analyses. SWS rejects about 10% of the vectors. The complete process is beyond the scope of the Tech Note. For a more detailed account of the procedures see Green, et al (1975).

SWS produces middle and high level vectors using the "manual method" which consists of the following steps:

a. Select cloud targets from a movie loop. Movie loops for both visual and IR data are available in 8 and 4km resolution. Typical loops consist of 5 images at 30 minutes intervals.

(1) The loop is fed through an overhead projector which focuses the image on a horizontal digitizing work area.

(2) A sheet of white paper is placed on the table and is used as a worksheet. By viewing the movie loop, meteorologists select potential cloud tracers and mark beginning and end points on the worksheet.

(3) Analysis times are currently 10, 16, and 22 GMT.

b. Determine cloud heights using the Man-Machine Interactive Processing System (MMIPS).

(1) IR data are ingested by the MMIPS computer to derive cloud top temperatures. Meteorologists works interactively with the computer to determine a representative cloud top temperature; they must determine the emissivity of the cloud so the proper temperatures are used. This step is important because many tracers are thin, allowing interference from the surface; that is, the sensed temperature is a combination of the cloud temperature and the temperature of the underlying surface. After this problem is addressed, a representative cloud temperature is processed by MMIPS; this is used to derive the height of the cloud tracer.

(2) Cloud tracer coordinates and estimated cloud temperatures are then digitized. Meteorologists identify the beginning and end points of cloud tracers on an X, Y coordinate board using a movable cursor. Meteorologists simultaneously enter the value of the cloud temperature.

(3) MMIPS then transforms these X, Y coordinates to earth located vectors. Additionally, MMIPS works interactively with NMC's massive data base to compare the MMIPS-derived cloud temperature and the current vertical temperature profile in the same region of the globe. The comparison yields a pressure level where the cloud temperature was measured. This level is rounded off to the nearest 10 mb.

c. Calculate wind vector for the derived cloud height using MMIPS. As with the low level winds, great efforts are made to insure the accuracy of the final product. Current analysis are used to edit all vectors before being released to the user community.

3. ACCURACY OF DATA. The term "accuracy" is misleading because to determine accuracy one would need to compare the information obtained against some established fact or ground truth. However, a ground truth regarding atmospheric motion does not exist - the true field of motion is an unknown. We now <u>imply</u> that we can determine this motion by tracking rawinsondes, radiosondes, or measuring the rate of rotation of an anemometer.

The most direct measurements of upper-level atmospheric motion are taken using radiosondes. Many studies undertaken to determine the accuracy of middle and high satellite winds have used radiosonde data as the comparative source, while ship reports and hourly observations were additonal sources used to determine the accuracy of the low level vectors.

Results of early studies (Hubert and Whitney, 1971) revealed large differences between individual rawinsonde measurements and satellite derived wind vectors. Comparison of between rawin winds at 850mb and satellite wind vectors in a later study (Hurbert and Whitney, 1974) showed that there was good agreement between the two sources when numerous satellite vectors and rawin measurements were used in a statistical "best fit analysis". The compatibility of these data sources therefore implied that the accuracy of the satellite derived winds are in good agreement with established accuracy of the rawinsonde derived winds. The main point is that although individual satellite vectors may deviate slightly from nearby radiosonde observations, one should not assume the satellite vectors are incorrect.

Results of the latest study (Hubert, 1976) revealed that approximately 68 percent of middle and high level satellite vectors deviated 15 knots or less from radiosondes, while low vectors deviated by approximately half this value. One of the results indicated that ... "the accuracy of most cloud vector (satellite derived) winds is about the same as that of Pibal observations, but a small portion (about 15%) contains significantly larger errors."

4. POSSIBLE USES OF THE DATA. In order to use the data, the data must be routinely received over teletype and plotted. Mission requirements will dictate ways to best use the data, but several suggested uses are given below. Instructions for decoding the satellite observation report and a sample bulletin are given in Appendices A and B.

Surface winds are available over many regions of the globe. Low level vectors can lead to a much better surface analysis, especially local analysis. Also, units supporting low level missions, such as Search and Rescue, can benefit by getting vectors in a more timely manner rather than "eyeballing" a wind or waiting on latest facsimile analysis.

Some of the uses of the high level wind vectors are given below.

a. To augment the upper air analyses with satellite vectors.

b. Blend satellite derived wind vectors with AIREPs to define the accuracy of NWP products, both in respect to forecast speeds as well as position of major synoptic features (troughs, ridges, pressure centers, etc.) defined by wind directions.

c. Satellite derived winds would also make excellent aircrew briefing aids when incorporated into existing briefing tools.

REFERENCES

Green, R., G. Hughes, C. Novak, and R. Schreitz, 1975, "The Automatic Extraction of Wind Estimates from VISSR Data," Paper Nr. 12 from NOAA Tech Memo NESS 64, Washington D.C., 155 pp.

Hubert, L, F., and L. F. Whitney, Jr., 1971,"Wind Estimation from Geostationary Satellite Pictures," Mon. Wea. Rev., 99, 665 -672.

_______________, 1974 "Compatibility of Low-Cloud Vectors and Rawins for Synoptic Scale Analyses," NOAA Tech. Rep. NESS 70, Washington D.C., 26 pp.

_______________, 1976, "Wind Determination from Geostationary Satellites," Proceeding of the 19th COSPAR meeting, Keynote paper, C. 36.1, 1-6.

Young, M., 1975, "The GOES Wind Operation," Paper Nr. 13 from NOAA Tech Memo NESS 64, Washington D.C., 155 pp.

APPENDIX A

SATELLITE WIND CODE

Satellite Observation (SATOB) is a rather involved and extensive WMO code used to transmit data derived from GOES systems to worldwide users. We only need to use those sections dealing with satellite derived winds and temperatures. The general heading of this bulletin is TWXXii. An explanation of the code groups are given below. A sample bulletin and plot are given in Appendix B.

Section 1 - Header

The format for this section varies depending on the source of the data.

For US data the header is:

TWXXii KWBC YYGGgg
YYXX YYGG/ $I_1I_2I_3$//

Line 1: TWXXii KWBC YYGGgg

TW: designator for satellite derived winds

XX: geographical designator - XN for northern hemisphere
XS for southern hemisphere
XX for unspecified area

i: bulletin number in series, 1-9. Each bulletin can contain up to 90 wind vectors, so an entire series may contain 810 wind vectors.

i: global octant designator:
0 - northern hemisphere, 0-90W
1 - northern hemisphere, 90W-180W
2 - northern hemisphere, 180E-90E
3 - northern hemisphere, 90E-0
5 - southern hemisphere, 0-90W
6 - southern hemisphere, 90W-180W
7 - southern hemisphere, 180E-90E
8 - southern hemisphere, 90E-0

Example: TWXN20 designates the second bulletin in the series for wind vectors between 0-90°W in the northern hemisphere.

KWBC: transmission center of NMC/NESS.

YY: day of the year of satellite observation.

GG: hour of the day of transmission (GMT).

gg: minute of the hour of transmission.

Line 2: YYXX YYGG/ $I_1I_2I_3$//

YY: [illegible]TOB designator.

XX: not [illegible]

YY: day of month designator (51-81 (day of month + 50); indicates that wind speed is in knots).

GG: hour of the observation (GMT).

$I_1I_2I_3$: designator for country or international agency operating GOES systems from which data are obtained.
000 - European
100 - Japan
200 - USA
300 - USSR
400 - 900 - reserved

For European data, the header is slightly modified.

The standard header is:

TSXXii EESA YYGG gg
YYXX YYGG/ $I_1I_2I_3$//

TS: designator for geostationary satellite derived wind data.

XX: same as US data.

i: bulletin number in series, (1,2,3) for octants 0 and 5; i+5 bulletin number in series (6,7,8) for octants 3 and 8.

i: global octant designator (same as US data).

Example: TSXN63 designates the first bulletin for wind vectors between 90E - 0^{o} in the northern hemisphere.

EESA: transmission center of German communication system.

YYGGgg: same as US data.

YYXX: same as US data.

YY: day of month (01-31; indicates wind speed in meters per second). The rest is the same as US data.

For Japanese data, the header is also modified. The standard header for Japanese satellite wind data is:

TSXXii RJTD YYGGgg
YYXX YYGG/ $I_1I_2I_3$//

TSXX: same as European data.

ii: bulletin identifier for hemispheric wind data; 10-14 for northern hemisphere, octant 2; 15-19 for southern hemisphere, octant 7.

Example: TSXS16 designates the second bulletin for wind vectors between 180E-90E.

RJTD: transmission center for Japanese communications system.

The remainder is in the same format as US data.

Section 2 - Data for wind and cloud-top temperatures at specified pressure levels; designated by 222.

$$222\ B_1B_2B_3nn\ U_{1a}U_{1o}U_{1a}U_{1o}/\ P_cP_cT_cT_cT_a ddfff\ P_cP_cT_cT_cT_a\ ddffff\ etc.$$

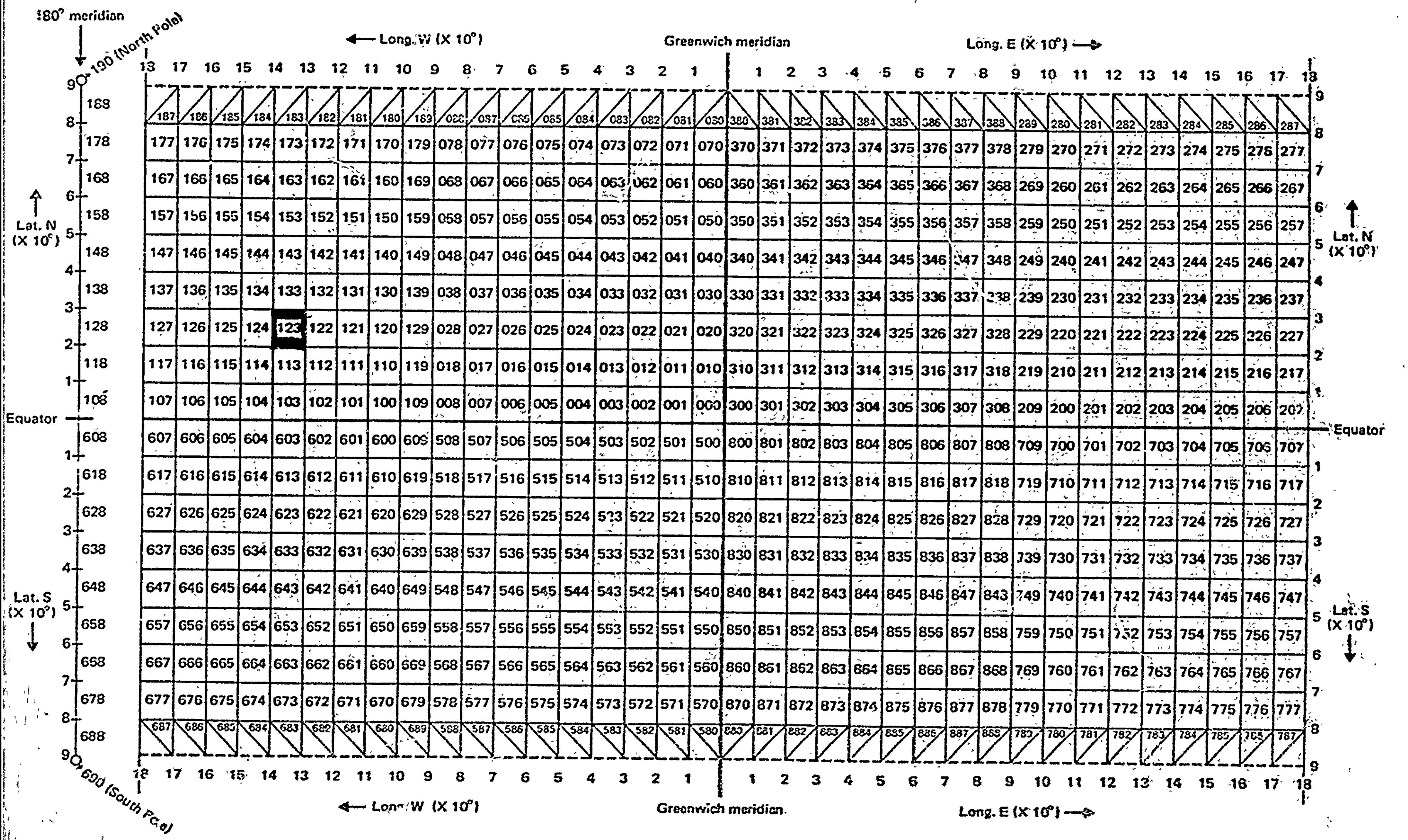
The three digit designator, $B_1B_2B_3$, specifies the octant and a 10x10 degree latitude/longitude box within which a specified number (nn) of wind vectors are located. This provides a quick reference to where the data are located and allows the forecaster to quickly determine if any data are available in the area of interest. Figure 1 provides a visual indication of the location of 10x10 degree blocks for wind vector locations. The three numbers identify one of the blocks in the figure; e.g., 023 identifies a location in octant 0, in the 10x10^{o} lat/lon block bounded by 20-30N and 30-40W. The breakdown of the remainder of the code identifies the location to the nearest degree and the wind data calculated for that point.

B_1: indicates the octant in which data are available.

B_2: latitude of 10x10^{o} lat/lon box in which wind vectors are located, e.g.

0 - 0 to 10^{o}N or S latitude, dependent on the octant.
1 - 10 to 20^{o}N or S, dependent on octant, etc.

B$_1$B$_2$B$_3$ — *Number designating a 10° × 10° square in a geographical grid*



B_3: longitude of 10x10° lat/lon box in which wind vectors are located, e.g.

0 - 0 to 10°E or W or 100 to 110°E or W, dependent on the octant, etc.
1 - 10 to 20°E or W or 110 to 120°E or W, dependent on the octant, etc.

Example: 123 - B_1 = 1, identifies octant 1, between 90°W and 180°W in the northern hemisphere.
B_2 = 2, latitude lies between 20 and 30°N.
B_3 = 3, longitude lies between 130 and 140°W.

Therefore 123 describes the 10x10° latitude/longitude box that is located within
20°N 130°W, 20°N 140°W
30°N 130°W, 30°N 140°W

This block is identified in Figure 1.

Note: The US operates two GOES systems, providing coverage from 49°N south to 49°S and from 20°W westerward to 170°E - for octants 0, 1, 2, 5, 6, and 7. The European GOES provides winds for octants 0, 3, 5, and 8. Japanese GOES provides winds for octants 2 and 7.

nn: number of wind vectors available in box given by $B_1B_2B_3$.

If nn > 5, then four vectors are defined on line 1, vectors 5-8 are on line 2, etc.

$U_{la}U_{lo}U_{la}U_{lo}$: last digit of latitude and longitude where two wind vectors are located to the nearest degree; these must be used in conjunction with $B_1B_2B_3$.

Example: 1234 used in conjunction with example above, $B_1B_2B_3$ = 123.
vector 1 is located at 2<u>1</u>°N 13<u>2</u>°W.
vector 2 is located at 2<u>3</u>°N 13<u>4</u>°W.

Note: Two vector wind points are contained in this example.

P_cP_c: pressure level in tens of mb where cloud top temperature exists and where wind vector is observed. P_cP_c is derived by converting cloud-top temperature to a pressure level using MMIPS.

T_cT_c: temperature (°C) at cloud top level. Value estimated from IR radiance data.

T_a: tenth of degrees C and designator of sign of T_cT_c. Odd integer - negative temperature; even integer - positive.

The code used is Code-Table 106 in FMH-4 or WMO Code 3931.

For US GOES data T_a = 1.

Code figure	Sign of temperature*	Temperature (tenths)
0	+	0.0 and 0.1
1	-	0.0 and 0.1
2	+	0.2 and 0.3
3	-	0.2 and 0.3
4	+	0.4 and 0.5
5	-	0.4 and 0.5
6	+	0.6 and 0.7
7	-	0.6 and 0.7
8	+	0.8 and 0.9
9	-	0.8 and 0.9

*Sign: + means above zero.
- means below zero.

ddfff: wind direction and speed in knots, where dd is in 5 degree increments.

If first f > 0 or f = 5, the speed > 100kts.

The European wind data are in meters per second; multiply speed values by 2 to convert to knots.

Section 3 - Wind data at estimated pressure levels.

333 $B_1B_2B_3$nn $U_{1a}U_{1o}P_eP_e$/ ddfff $U_{1a}U_{1o}P_eP_e$/ ddfff

$B_1B_2B_3$: same as in section 2.

nn: same as in section 2; there can be up to 5 wind vectors per line in this section. If nn > 5, then 6th vector starts the new line.

$U_{1a}U_{1o}$: same as in section 2.

P_eP_e: estimated pressure level in tens of mb where cloud vector was observed at $U_{1a}U_{1o}$.

ddfff: same as in section 2.

A example of a complete bulletin is given below.

TWXXii KWBC YYGGgg
YYXX YYGGg $I_1I_2I_3$//
222 $B_1B_2B_3$nn $U_{1a}U_{1o}U_{1a}U_{1o}$/ $P_cP_cT_cT_cT_a$ ddfff $P_cP_cT_cT_cT_a$ ddfff ....
333 $B_1B_2B_3$nn $U_{1a}U_{1o}P_eP_e$/ ddfff $U_{1a}U_{1o}P_eP_e$/ ddfff ....

A sample TWXN bulletin for the eastern Pacific for 1000Z 8 Jan 79 and a plot of 900mb winds on the 00Z 850mb analysis are given in Appendix B. Note the winds plotted are located in the areas identified by block numbers 132-135, 142-145, 152-155 (ref Fig 1). Satellite winds are identified using the special notation to differentiate these from radiosonde winds.

APPENDIX B

SAMPLE BULLETIN

```
TWXN11 KWBC 081000
YYXX 5810/ 200//
222 10902 3148/ 57000 04014 58000 07514
    10602 7320/ 19541 30541 19541 28034
    11101 60/// 22471 27543
    11205 5978/ 23471 23572 22471 23087 9543/ 22471 23593 22471 24544
          70/// 23471 24048
    11302 9892/ 26431 30038 27431 26541
    11601 19/// 19541 29045
    11702 0623/ 19541 23543 19541 26044
    12102 5975/ 26431 25064 27431 26064
    12201 19/// 27431 26552
    12304 8947/ 29501 30083 28501 32583 3171/ 27431 25063 39431 28046
    12403 3825/ 20541 30062 22541 30566 75/// 22541 29583
    12503 7844/ 19541 25587 18541 27077 51/// 19541 27058
    12603 5774/ 27351 25094 22471 25100 87/// 20531 24134
    12701 91/// 52131 25049
    13201 88/// 26531 22076
    13301 31/// 26501 26572
    13402 3520/ 25501 28602 29501 30101
    13502 3974/ 18531 23155 23531 20617
    13601 12/// 18531 23642
    13702 1131/ 52131 24046 56131 25539
    14201 07/// 26331 18552
    14302 2125/ 24531 11536 22531 09025
    14401 83/// 43351 14528
    14501 24/// 26531 19092
333 10903 8320/ 20519 5590/ 12507 3390/ 05005
    10005 5590/ 11512 5090/ 10517 3390/ 05005 0590/ 12007 0090/ 05017
    10106 8890/ 11011 8390/ 07015 5090/ 14015 3890/ 08023 3390/ 08019
          0090/ 11529
    10205 0090/ 11527 8390/ 09527 3890/ 06026 3390/ 10514 0590/ 12024
    10304 8890/ 09523 3890/ 08028 3390/ 08037 0090/ 09032
    10408 8890/ 09528 8390/ 09028 5590/ 11028 5090/ 09530 3890/ 11024
          3390/ 10033 0590/ 10535 0090/ 09528
    10506 8890/ 11029 8390/ 08028 5590/ 09524 5090/ 09027 0590/ 08032
          0090/ 09031
    10601 5090/ 09527


TWXN21 KWBC 081000
YYXX 5810/ 200//
333 10706 8890/ 10506 5590/ 07523 3890/ 10510 3390/ 11026 0590/ 09522
          0090/ 09520
    10801 5090/ 09519
    11902 0020/ 22524 3390/ 07019
    11003 3890/ 06507 3390/ 07513 0590/ 10508
    11106 8890/ 07010 5090/ 06007 3890/ 08019 3390/ 10023 0590/ 05510
          0090/ 07515
    11201 0090/ 08017
    11301 0590/ 10010
    11403 3390/ 10533 0590/ 12528 0090/ 09526
    11507 8890/ 16511 5590/ 13525 5090/ 12018 3890/ 11521 3390/ 10523
          0590/ 09021 0090/ 10533
    11606 8890/ 21020 8390/ 21012 5090/ 14022 3390/ 15020 0590/ 11523
          0090/ 15011
    11703 8390/ 23516 5590/ 25507 5090/ 17510
    12902 3390/ 33507 0590/ 04506
    12001 7525/ 26081
    12101 5590/ 34016
    12202 5590/ 28516 0590/ 07018
    12302 3890/ 26020 3390/ 22016
    12403 8390/ 25038 3390/ 22025 0090/ 17516
    12501 0590/ 20010
    12605 5090/ 22035 3890/ 26035 3390/ 23531 0590/ 22013 0090/ 22023
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13401 5090/ 25020
13503 8950/ 24045 9750/ 22039 8890/ 22533
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3390/ 25539 0590/ 27037
13707 8890/ 29022 8390/ 32521 5590/ 29017 5090/ 29030 3890/ 29022
0590/ 29021 0090/ 26529
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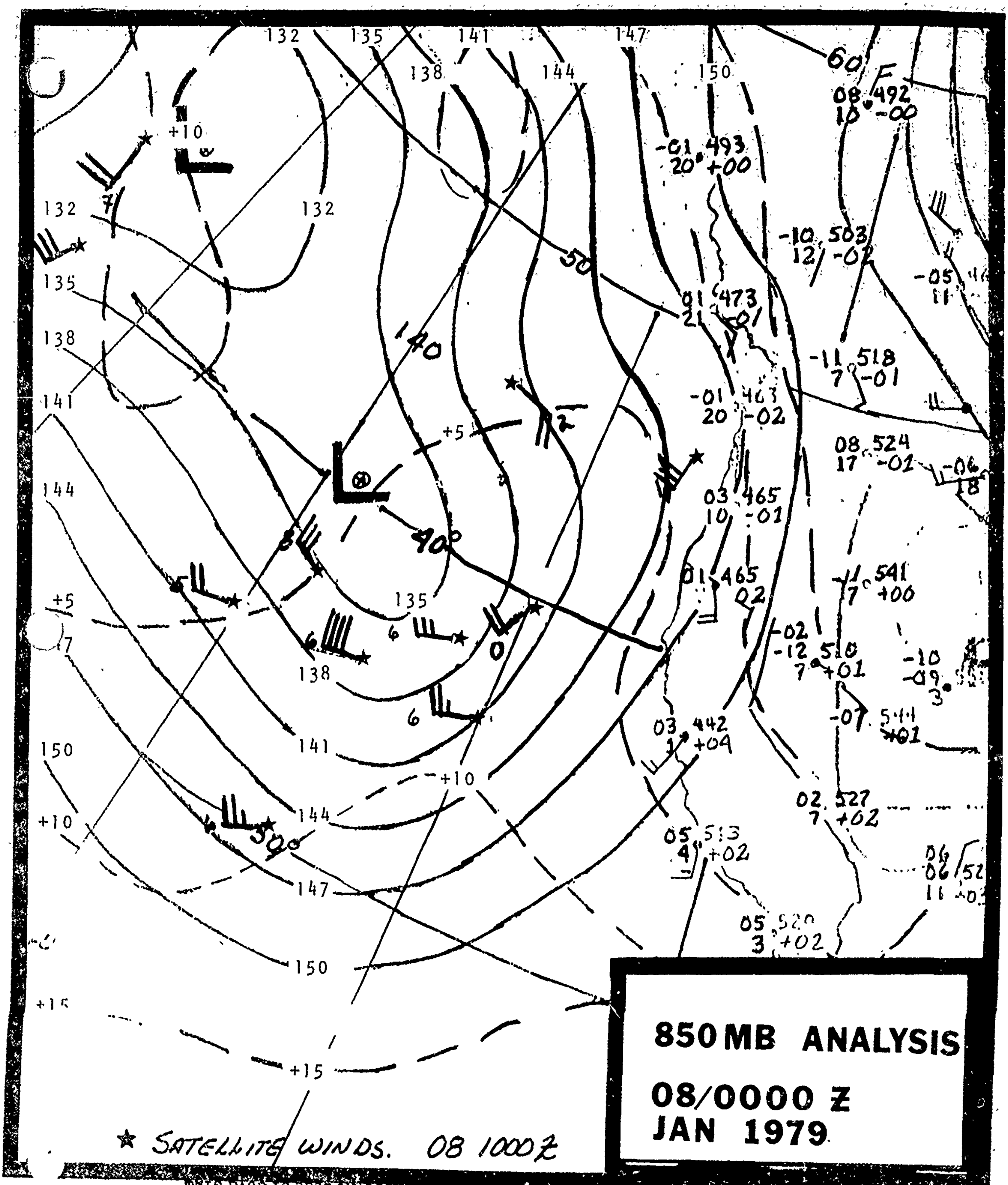
14503 1650/ 20536 3890/ 16520 0590/ 21032



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